3.0 Model Implementation

The initial modeling phase implemented by ADEQ uses the Hydrologic Simulation Program FORTRAN (HSPF) to simulate the hydrology and dissolved copper transport in the various reaches of the Queen Creek watershed (ADEQ, 2010). HSPF is a component of the US EPA BASINS (USEPA, 2001) program which integrates Geographic information System (GIS), data analysis, and modeling to support watershed based analysis. HSPF is a hydrologic, watershed-based water quality model that explicitly accounts for the specific watershed physical conditions, the variations in rainfall and climate, and the sources of dissolved copper and total lead in the Queen Creek watershed. The HSPF model was selected because of its dynamic nature and is well suited for the hydrologic and water quality applications in the Queen Creek watershed.

The goals of the modeling approach are to develop a predictive tool for the Queen Creek watershed that can:

- represent the watershed characteristics
- represent the point and non-point sources pollutant loads and their respective contribution
- allow for direct comparisons between the in-stream conditions and the water quality standard
- estimate the in-stream pollutant concentrations and loadings under various hydrologic conditions

The results from the developed model are subsequently used to develop the watershed-basis analyses using the estimated existing-conditions loads for dissolved copper and total lead. The modeling process in HSPF starts with the delineation of the watershed into smaller model segments followed by the development of the physical and land use data that describe each model segment. ADEQ used the EPA BASINS platform to perform the watershed delineation where the Queen Creek watershed was delineated into 95 smaller subwatersheds (model segments) to represent the watershed characteristics and to improve the accuracy of the HSPF model. This division of subbasins to segments delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. **Figure 2-1** depicts the delineated subwatersheds. This division of the Queen Creek watershed into smaller model segments also determines the landuse and geology within each model segment.

The HSPF model requires several standard and optional modules in order to adequately simulate the hydrology and pollutant fate and transport of the watershed. The following HSPF modules were invoked in the Queen Creek HSPF implementation: PERLND, IMPLND, RHCRES, HYDR, ADCALC, ATEMP, SNOW, PWATER, IWATER, SOLIDS, SEDMNT, SEDTRN, PQUAL, IQUAL, and GQUAL. The algorithms used in these modules are described in the HSPF Users Manual (EPA, 2001).

Given the flashy nature of Queen Creek and availability of high frequency stream stage and weather logger data, the time-step for the model was set at 15 minutes. The model's simulation period spanned from the fall 2006 (when most of the stage loggers were initially deployed) to February 29, 2008.

3.1 Hydrology Calibration

The HSPF model uses rainfall and other meteorological records to simulate the hydrologic cycle, which includes evapotranspiration, surface runoff, interflow, baseflow, soil moisture, snowpack depth and water content, snowmelt, and groundwater recharge. Calibrating the hydrology in HSPF involves developing a set of representative values for the parameters used in HSPF algorithms that best describe the watershed conditions. These parameters are based on the available watershed physiographic data (soil types, topography, and land use/geology) and hydrographic data (steam network and reaches). Model calibration is a repetitive process of running the HSPF model under varying parameter values, and comparing the results with the observed flow. Sensitivity analysis is always during the calibration process where input parameters are adjusted until the modeling results are acceptable, which includes agreement between the model output and the observed flow data.

Simulating the hydrology in ephemeral and intermittent streams is quite challenging because of the water losses to groundwater in the alluvium. In fact, the hydrologic and associated pollutant transport processes are significantly affected spatially and temporally by the intermittent nature of Queen Creek. Stream flows and the corresponding pollutant loads in intermittent streams are generally influent, or subject to downstream volume decreases. These decreasing flow volumes principally are due to transmission losses resulting from infiltration of streamflow into the unconsolidated alluvium forming channel boundaries, losses resulting from overbank flooding, and evaporation of floodwaters (USEPA, 2008).

Queen Creek transitions from a steep gradient bedrock streambed, to an alluvial bedded, low gradient stream below the Town of Superior. The initial HSPF model runs consistently over estimated discharge rate and volume at most monitoring stations in the Queen Creek watershed. To mimic these transmission losses, a second exit was added to the HSPF FTABLES at several reaches of the Queen Creek channel. FTABLES are tables of stream geometry with depth/discharge relationships. The addition of this second channel exit helped address the observed water losses and resulted in a robust hydrology calibration that and mimics quite well the observed data. During the recalibration of the model for dissolved copper the hydrology simulation was slightly adjusted to generate a better fit between the observed and simulated stream flows. **Table 3-1** presents the final HSPF hydrology parameterization. The typical and possible parameter ranges in **Table 3-1**were adapted from EPA BASINS Technical Note 6 (EPA, 2000).

Figures 3-1 and **3-2** present the hydrology calibration in the Oak Flat and Potts Canyon, respectively. The complete hydrology calibrations results, presented in **Appendix A,** indicate a very good agreement between observed and simulated flows.

Table 3-1: Queen Creek Watershed HSPF Calibration Parameters - Final Parameter Values							
Parameter	**Definition**	**Units**	**Typical**		**Possible**		**Final Calibration Value/ Ranges**
			Min	**Max**	**Min**	**Max**	
LZSN	Lower zone nominal soil moisture	inch	3	8	2	15	2.5-5.0
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.07-0.25
LSUR	Length of overland flow	Ft	200	500	100	700	150 - 250
SLSUR	Slope of overland flow plane	None	0.01	0.15	0.001	0.3	0.11 – 0.54
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.98
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.4 – 0.75
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.10
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0.0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	0.01
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.05	2	0.3 - 0.4
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.05 – 0.2
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	1.0 – 2.0
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.1 – 0.5
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	0.2 - 0.35
POTFW	Constituent Potency Factor	mg/ton	-	-	-		Varies with pollutant and soil Tables 3-2 and 3-14
IOQC	Constituent concentration in interflow	mg/ft^3	-	-	-	-	Varies with pollutant and soil Tables 3-2 and 3-14
AOQC	Constituent concentration in active groundwater	mg/ft^3	-	-	-	-	Varies with pollutant and soil Tables 3-3 and 3-14

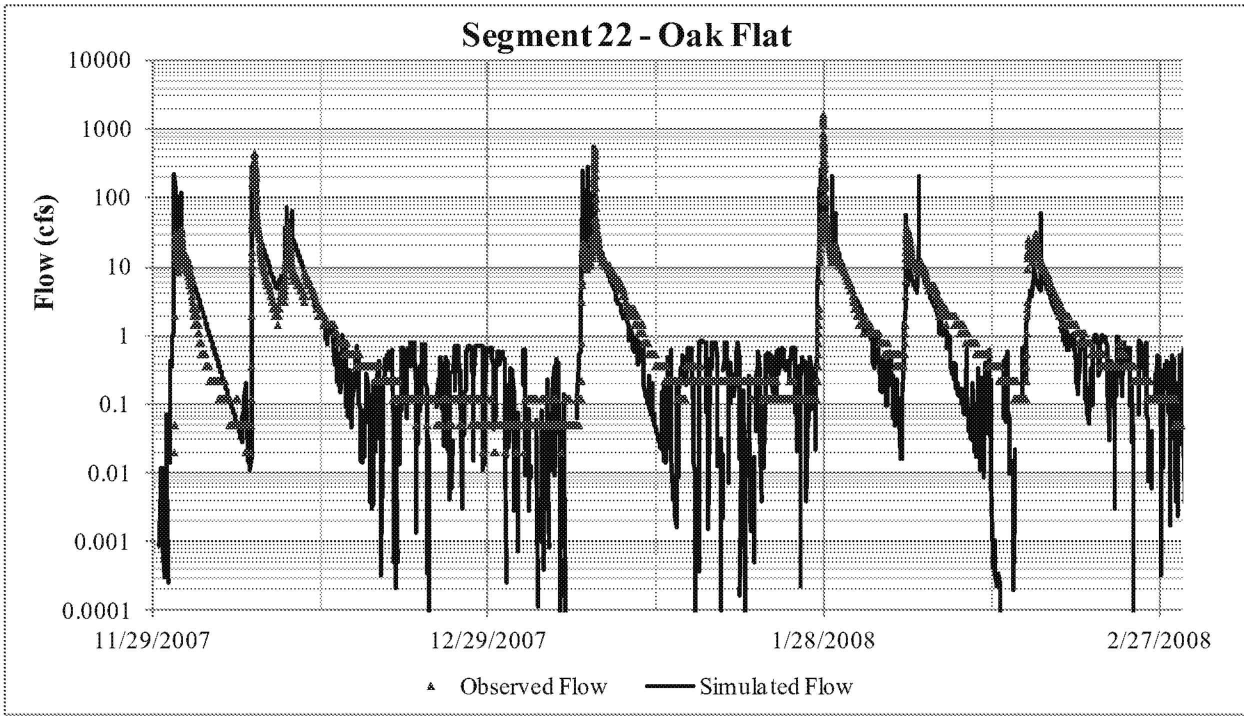

Figure 3-1: Observed and Simulated Flows at Model-Segment 22 – Oak Flat

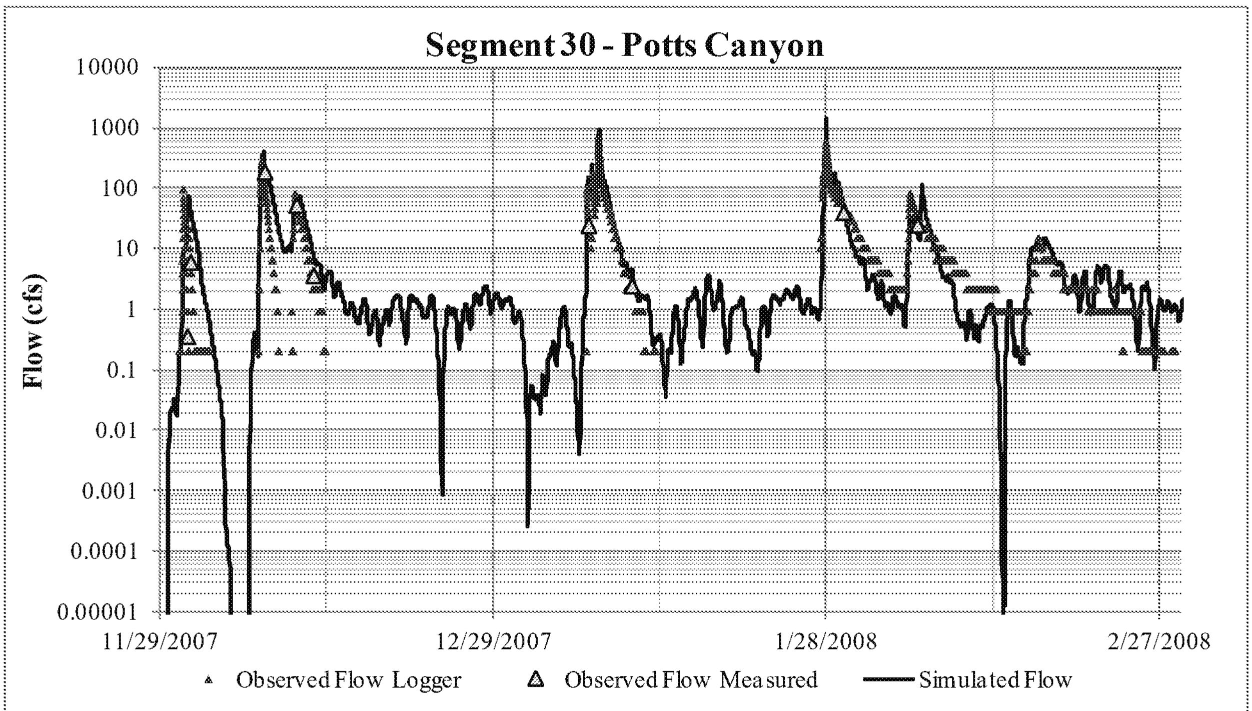

Figure 3-2: Observed and Simulated Flows at Model-Segment 30 – Potts Canyon

3.2 Dissolved Copper Recalibration

Calibrating the water quality component involves developing the adequate model parameterization that best describe the dissolved copper sources and environmental conditions in the Queen Creek watershed. It is an iterative process in which the model results are compared to the available in-stream dissolved copper data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations. The HSPF PQUAL subroutine of the PERLND module was used to simulate the washoff of copper from pervious land segments (Washoff Potency Factor: POTFW) as well as to specify dissolved copper concentrations in interflow (IOQC) and baseflow (AOQC).

As previously implemented with other similar HSPF models in Arizona (ADEQ, 2006), the Queen Creek model assumes that the land-based pollutants can be modeled during precipitation events as detached sediment particles. In fact, PQUAL offers two options for simulating the washoff of a pollutant: (1) by accumulation/deposition and washoff (QUALOF); or (2) by association with detached sediment erosion and washoff (QUALSD). Neither of these methods was specifically designed for the simulation of dissolved metals in runoff, which do not necessarily over time nor are directly attached to sediment. Since the QUALSD can be used to model constituents that are highly correlated with precipitation and runoff, it was selected to simulate the dissolved copper the Queen Creek watershed.

The parameters of the HSPF PQAL module were first estimated using as a starting point the estimated dissolved copper concentration for a single lithology (**Table 3-3**). This soil dissolved concentration was assigned to the dissolved copper concentrations in interflow (IOQC in lb/ft^3) and in the baseflow (AOQC in lb/ft^3). The Washoff Potency Factor (POTFW in mg of copper per ton of sediment) was developed using similar approach used in the interim modeling report (ADEQ, 2010) and also in previous TMDL developed in Arizona (ADEQ, 2006).

Using this consistent approach allows simulation of a constant event mean concentration of dissolved copper from each pervious land segment using as a guide water quality concentrations that were representative of runoff from relatively undisturbed portions of the Queen Creek watershed, some of which represent a single lithology. This approach is consistent with ADEQ initial parameterization of the model where all three PQUAL parameters were first estimated for each single lithology-soil type and using exiting monitoring data.

In fact and during the initial parameterization of the model, ADEQ collected water quality samples that were representative of runoff from relatively undisturbed portions of the Queen Creek watershed, some of which represent a single lithology. The mean dissolved copper concentrations observed and the initial PQUAL parameter values, estimated by ADEQ during the initial phase of the modeling, were used as a starting point to develop the water quality model parameterization. After several iterative approaches, it was judged more efficient to develop PQUAL parameters on a subbasin basis. In other words, all the PQUAL parameters are the same for each soil-landuse within each specific subbasin. The PQUAL parameters were estimated iteratively by varying the dissolved copper concentration for each land use type in the sub-basin until an acceptable fit is achieved between the simulated and observed dissolved copper concentrations.

The water quality calibration proceeded from the most upstream reach (segment 94) to the downstream reach (segment 25). Further modeling refinements were made at several monitoring stations; using the hard rock copper data as a guide; to achieve a better fit between observed and simulated average dissolved concentrations. **Table 3-2** depicts the final PQUAL value for each soil landuse type within each of the sub-basins in the Queen Creek watershed. The revised PQAL values are to some extent slightly different that the initial values estimated by ADEQ. For instance, the estimated POTFW values for Pinal Schist were initially the same in the entire Queen Creek watershed (1,236 mg/ton) and now vary from 1,030 mg/ton (Silver King Wash) to 1,442 mg/ton (Happy Camp Canyon).

Table 3-2: Copper HSPF PQUAL Parameters Summary by Sub-Basin and Soil-Landuse Type

Geology/ Landuse	Parameter	Potts Canyon	Happy Camp Canyon	Silver King Wash	Apex Wash	RCC Superior Wash	Queen Creek	Oak Flat	Arnett Creek	Alamo Canyon	Reymert Wash
Pinal Schist	Cu Conc. (ug/L)	12	14	10					15	10	12.5
	POTFW (mg/ton)	1,236	1,442	1,030	-	-	-	-	1,545	1,030	1,288
	IOQC (lb/ft^3)	0.34	0.396	0.283	-	-	-	-	0.425	0.283	0.354
	AOQC (lb/ft3)	0.34	0.396	0.283	-	-	-	-	0.425	0.283	0.354
Apache Group	Cu Conc (ug/L)	8	20	5	5	20	13		6.5		
	POTFW (mg/ton)	824	2,060	515	515	2,060	1,339	-	670	-	-
	IOQC (lb/ft^3)	0.226	0.566	0.142	0.142	0.566	0.368	-	0.184	-	-
	AOQC (lb/ft3)	0.226	0.566	0.142	0.142	0.566	0.368	-	0.184	-	-
Granite Crystalline	Cu Conc (ug/L)	10		8			8		8		6
	POTFW (mg/ton)	1,030	-	824	-	-	824	-	824	1,442	618
	IOQC (lb/ft^3)	0.283	-	0.226	-	-	0.226	-	0.226	0.396	0.17
	AOQC (lb/ft3)	0.283	-	0.226	-	-	0.226	-	0.226	0.396	0.17
Volcanic	Cu Conc (ug/L)	9	15	11	15		28		8	9	
	POTFW (mg/ton)	927	1,545	1,133	1,545	-	2,884	-	824	927	-
	IOQC (lb/ft^3)	0.255	0.425	0.311	0.425	-	0.792	-	0.226	0.255	-
	AOQC (lb/ft3)	0.255	0.425	0.311	0.425	-	0.792	-	0.226	0.255	-
Alluvium	Cu Conc (ug/L)	4	8	12	5	10	10		5	10	5
	POTFW (mg/ton)	412	824	1,236	515	1,030	1,030	-	515	1,030	515
	IOQC (lb/ft^3)	0.113	0.226	0.34	0.142	0.283	0.283	-	0.142	0.283	0.142
	AOQC (lb/ft3)	0.113	0.226	0.34	0.142	0.283	0.283	-	0.142	0.283	0.142
Mining Milling Metal	Cu Conc (ug/L)	275		346	750	50	150	25	275		25
	POTFW (mg/ton)	28,325	-	35,600	77,250	5,150	15,450	2,575	28,325	-	2,575
	IOQC (lb/ft^3)	7.783	-	9.78	21.225	1.415	4.245	0.708	7.783	-	0.708
	AOQC (lb/ft3)	7.783	-	9.78	21.225	1.415	4.245	0.708	7.783	-	0.708
Sedimentary	Cu Conc (ug/L)	11	23	12	10	20	14		14	20	
	POTFW (mg/ton)	1133	2369	1236	1030	2060	1442	-	1442	2060	-
	IOQC (lb/ft^3)	0.311	0.651	0.34	0.283	0.566	0.396	-	0.396	0.566	-
	AOQC (lb/ft3)	0.311	0.651	0.34	0.283	0.566	0.396	-	0.396	0.566	-
Tuff	Cu Conc (ug/L)		15	19.0	19	40.0	22	47.4	12.0	20.0	
	POTFW (mg/ton)	-	1,545	1,957	1,957	4,120	2,266	4,878	1,236	2,060	-
	IOQC (lb/ft^3)	-	0.425	0.538	0.538	1.132	0.623	1.34	0.34	0.566	-
	AOQC (lb/ft3)	-	0.425	0.538	0.538	1.132	0.623	1.34	0.34	0.566	-
Urban Industrial	Cu Conc (ug/L)				15.0	15.0	15.0				
	POTFW (mg/ton)	-	-	-	1,545	1,545	1,545	-	-	-	-
	IOQC (lb/ft^3)	-	-	-	0.425	0.425	0.425	-	-	-	-
	AOQC (lb/ft3)	-	-	-	0.425	0.425	0.425	-	-	-	-

The water quality calibrations were performed at each water quality monitoring station located at each subbasin outlet and at several stations located in the Queen Creek main stem (**Table 3-1**). The water quality calibrations compare the simulated copper time-series and the observed dissolved copper observations during the period spanning from November 29, 2007 to February 27, 2008. **Figures 3-3** and **3-4** depict the dissolved copper calibration in Oak Flat (Segment 22) and Queen Creek (Segment 92), respectively. The complete dissolved copper calibration results are presented in **Appendix B** indicating a good agreement between observed and simulated concentrations.

3.2.1 Existing Conditions Scenarios

The calibrated HSPF model for hydrology and dissolved copper is then used to estimate pollutant loads under various scenarios. One of the key challenges in the TMDL development process is how to define the critical conditions for a receiving waterbody impacted by nonpoint sources. Knowledge of the critical conditions could help identify the potential feasible allocation scenarios needed to be taken to meet water quality standards. The common approach used to define the critical conditions where nonpoint source pollution dictates the water quality is to use longer simulation period and average the resulting water quality loads. Using longer simulation periods assume that the most critical conditions will be captured during the selected representative hydrologic period. However, such an approach might not applicable in the Queen Creek watershed due the intermittent hydrology where the creek flows continuously only at certain times of the year.

An event-based approach to address the critical conditions is deemed more adequate to use in the Queen Creek watershed. This event-based approach explicitly addresses the critical conditions as a combination of stream flow linked to various magnitudes of storm events using several frequencies of occurrences. The key advantage of the event-based approach over continuous simulation is its ability to examine impacts of management options under synthetic design storms; which can be used to assess the risk associated with a specific pollutant load reduction scenario. Thus, the resulting nonpoint source management plan could be linked with its corresponding return period to determine the reasonable assurance of any future TMDL implementation.

In order to estimate the pollutant loads at various storm intensities and under varying critical conditions and frequencies, a series of synthetic storms was imposed over the calibrated Queen Creek watershed model. In all, five storms are modeled ranging from the 2-year 1-hour storm event to the 100-year 24-hour event. The 2-year, 1-hour event precipitation total was distributed using the SCS Type II curve. The four other 24-hour events were distributed by the SCS Type IA curve, which is judged to be more representative of the larger winter storms observed in Arizona (ADEQ, 2010).

The synthetic storm scenarios modeling period begins on February 1st, 2008 and runs through August 30, 2008. The month of February is the model initializing and stabilization period, and is populated with actual weather data, and the synthetic storm begin on March 1st with the remainder of each month is dry (ADEQ, 2010. Therefore, each synthetic storm scenario was run separately and all begin on March 1st.

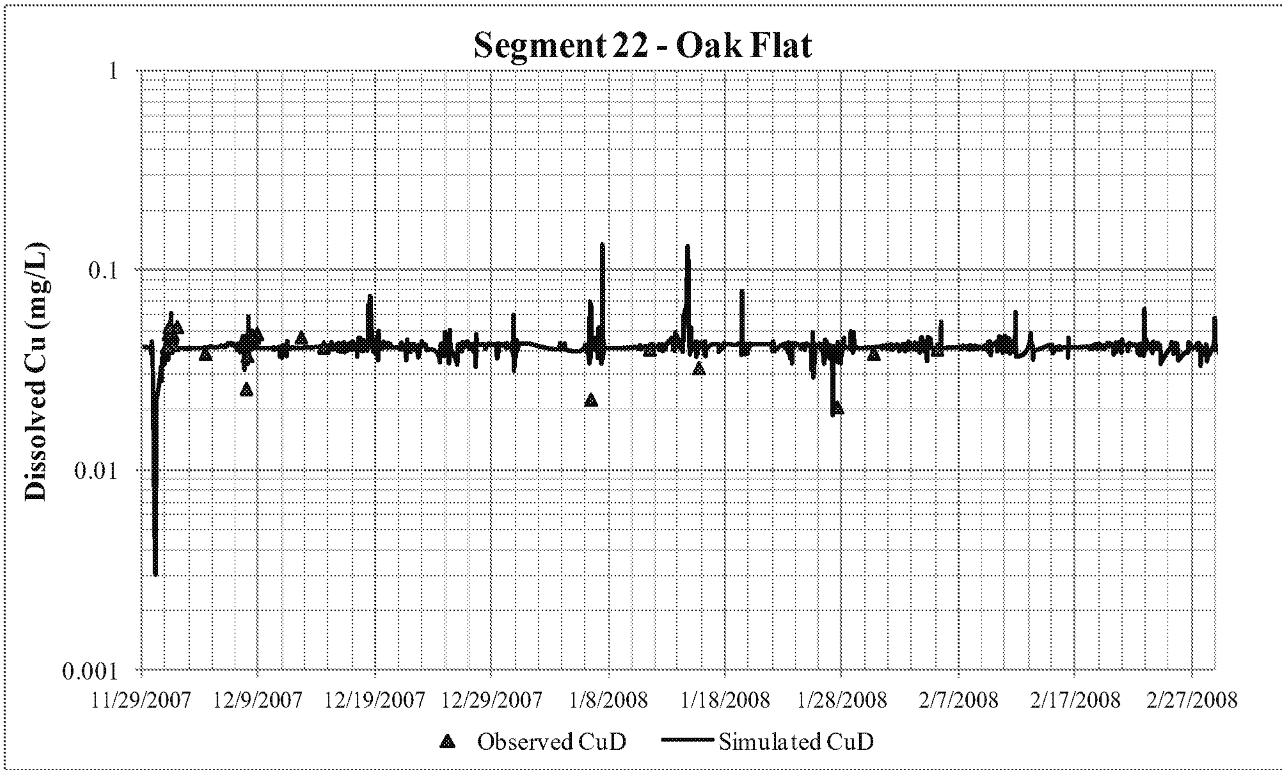

Figure 3-3: Observed and Simulated Dissolved Copper at Model-Segment 22 – Oak Flat

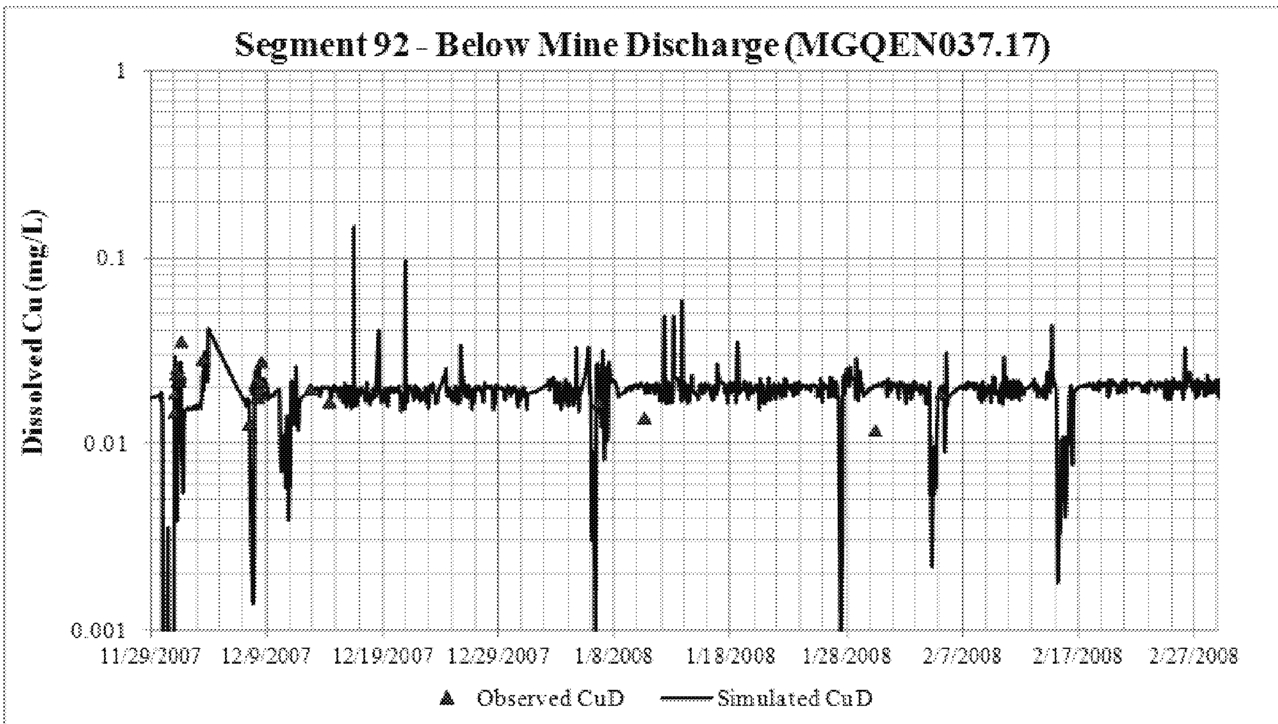

Figure 3-4: Observed and Simulated Dissolved Copper at Model-Segment 92 – Queen Creek

Data on precipitation depths and distributions for the synthetic storms were obtained from the National Oceanic and Atmospheric Administration (NOAA) Precipitation-Frequency Atlas of the United States, NOAA Atlas 14, Volume 1, Version 4. **Table 3-3** presents the characteristics of the synthetic storms. In addition to rainfall data, the HSPF model requires additional data such potential evapotranspiration and air temperature; these additional meteorological data were extracted from similar time periods from the ADEQ 2007 weather data set used for the calibration. Similar to the HSPF model calibration, the synthetic storm weather data was distributed to each subbasin based on proximity to the rain gage and elevation. The synthetic storms conditions were then imposed on the calibrated HSPF model to implement the Existing Conditions Scenario.

Table 3-3: Characteristics of the Synthetic Storms

Storm Event Return Period and Duration	SCS Precipitation Distribution Type	Omya Rain Gage Precipitation Depth (inches)	Boyce Rain Gage Precipitation Depth (inches)
100-yr, 24-hr	IA	6.20	4.64
25-yr, 24-hr	IA	4.89	3.67
10-yr, 24-hr	IA	4.08	3.06
2-yr, 24-hr	IA	2.78	2.08
2-yr, 1-hr	II	1.18	0.99

The resulting 24-hour average dissolved copper concentrations and the 24-hour loads are depicted for each subbasin and synthetic storm in **Tables 3-4** and **3-5** respectively. Under each synthetic storm condition, the compliance with the A&Ww acute and chronic criteria was assessed at each representative model-segment using the average observed hardness and the 24-hour average predicted copper concentration (**Table 3-4**).

Table 3-4: Existing Conditions 24-Hour Average Dissolved Copper Concentrations (µg/L)

Subwatershed	Average Hardness (mg/L)	Acute Criterion (ug/L)	Chronic Criterion (ug/L)	Existing Conditions 2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	26.4	3.8	2.9	35.1	32.7	33.2	33.6	35.0
QC Hwy 60 Seg 17	103	13.8	9.2	20.6	18.6	18.8	18.8	19.2
QC Magma Avenue Seg 91	60	8.3	5.8	23.4	22.9	22.1	22.8	23.6
QC Mary Avenue Seg 38	90	12.2	8.2	22.3	13.5	16.9	17.3	18.6
QC below Mine Disch. Seg 92	96	12.9	8.6	12.5	0.8	12.3	14.1	15.4
Apex Wash Seg 50	182	23.6	14.9	13.1	3.9	11.4	13.0	14.5
QC Arboretum Seg 47	373	46.5	27.6	4.7	7.0	11.5	12.6	13.7
Silver King Wash Seg 45	257	32.7	20.1	14.3	9.1	10.1	10.3	10.5
Happy Camp Canyon Seg 42	400	49.6	29.3	10.2	10.6	13.0	14.5	15.3
Arnet Creek Seg 46	98	13.2	8.8	9.0	4.3	5.7	5.9	6.3
Alamo Canyon Seg 49	115	15.3	10.1	6.8	6.9	8.0	8.6	8.8
Potts Canyon Seg 30	120	16.0	10.5	10.6	6.0	7.3	7.3	7.4
Reymert Wash Seg 28	400	49.6	29.3	5.7	6.8	7.8	8.5	8.9
QC Outlet Seg 25	109	14.6	9.6	14.4	12.4	12.1	12.3	12.4

Average Concentration Exceeds Chronic Criterion
Average Concentration

ED_013248_00000678-00009

The dissolved copper compliance analysis (**Table 3-4**) is performed at each subbasin outlet and along representative monitoring stations (model segments) along the Queen Creek main stem. In other words, the resulting water quality at each subbasin outlet is considered representative of the water quality conditions within the whole subbasin. For instance, the concentrations and loads at model-segment 22 (Oak Flat Subbasin) take into account all the hydrologic and water quality processes occurring in all the upstream segments including model-segments 23, and 24 that feed into model-segment 22. The reported loads at subbasin outlet cannot be considered as the cumulative loads from the upstream segments in the subbasin, since the nature of a watershed model is to transport subsequently all these loads and account for all the sources (addition/increase of a load; e.g., nonpoint source loads) and sinks (decrease of a load; e.g. transmission losses, and adsorption to suspended sediment, etc…) occurring in each of the upstream segments. This is the essence of a watershed-basis analysis when using a model such as HSPF that simulates hydrology and pollutant processes at each model segment and transport the flow and pollutant load to each subsequent segment and down to the outlet of the subbasin and ultimately to the outlet of the entire Queen Creek watershed. Presenting the modeling results at the outlet of a subbasin or a watershed is the recommended approach to use in watershed-based studies.

Table 3-5: Existing Conditions 24-Hour Average Dissolved Copper Loads (kg)

Subbasin/Modeling Segment	Existing Conditions				
	2Y-1Hr	2Y-24Hr	10Y-24Hr	25Y-24Hr	100Y-24Hr
Oak Flat Seg 22	0.197	0.243	1.372	2.356	3.950
QC Hwy 60 Seg 17	0.040	0.080	0.704	1.318	2.306
QC Magma Avenue Seg 91	0.259	0.330	2.220	4.166	7.573
QC Mary Avenue Seg 38	0.255	0.300	2.151	4.070	7.472
QC below Mine Disch. Seg 92	0.079	0.003	1.118	2.906	6.230
Apex Wash Seg 50	0.023	0.004	0.086	0.236	0.569
QC Arboretum Seg 47	0.008	0.001	0.352	1.549	4.861
Silver King Wash Seg 45	0.021	0.004	0.060	0.148	0.524
Happy Camp Canyon Seg 42	0.028	0.004	0.031	0.161	0.673
Arnet Creek Seg 46	0.024	0.005	0.164	0.766	2.528
Alamo Canyon Seg 49	0.017	0.003	0.025	0.116	0.484
Potts Canyon Seg 30	0.097	0.006	0.370	0.723	1.745
Reymert Wash Seg 28	0.008	0.002	0.013	0.061	0.259
QC Outlet Seg 25	0.101	0.007	0.356	1.497	6.958

The dissolved copper concentrations and loads resulting from the five synthetic storms are presented at the outlet of each subbasin and at several representative model-segments in the main stem of Queen Creek including the watershed outlet (highlighted in green in **Tables 3-5**). The compliance analysis indicates that under all five synthetic storm conditions, the upper reaches (model-segments 22, 17, 91, and 38) of Queen Creek will exhibit exceedances of the acute and chronic dissolved copper criteria under all five synthetic storms conditions.

Because of the significant transmission losses of flow and pollutant loads in the Queen Creek watershed, the intensity, duration, and return period of each synthetic storm affect differently the dissolved copper loads at downstream model-segments in the main stem of Queen Creek. This is indicated in **Table 3-5** where under low intensity storm events, the copper loads decrease along the Queen Creek main stem, while these loads increase under the largest 100-year event where tributary contributions increase the downstream flows and loads even while the losses are still considerable. The dissolved copper concentrations and loads presented in **Tables 3-4 and 3-5** are used to estimate the magnitude the allowable loads and the related load reductions at each subbasin outlet and model segment in the main stem of Queen Creek. **Table 3-6** presents the allowable dissolved copper loads and the corresponding reduction using the most stringent dissolved copper chronic criterion.

Table 3-6: Existing Conditions Scenario Dissolved Copper Allocation Analysis

Subbasin/Modeling Segment	Maximum Allowable 24-Hour Load (kg)					Estimated Dissolved Copper Reductions to Comply with the Maximum Allowable Load (%)				
	2Y 1Hr	2Y 24Hr	10Y 24Hr	25Y 24Hr	100Y 24Hr	2Y 1Hr	2Y 24Hr	10Y 24Hr	25Y 24Hr	100Y 24Hr
Oak Flat Seg 22	0.016	0.021	0.119	0.201	0.324	91.8	91.2	91.4	91.5	91.8
QC Hwy 60 Seg 17	0.018	0.040	0.344	0.644	1.103	55.4	50.6	51.1	51.1	52.2
QC Magma Avenue Seg 91	0.064	0.083	0.581	1.058	1.857	75.3	74.7	73.8	74.6	75.5
QC Mary Avenue Seg 38	0.094	0.182	1.042	1.926	3.288	63.3	39.4	51.6	52.7	56
QC below Mine Disch. Seg 92	0.055	0.032	0.786	1.782	3.499	30.8	0	29.7	38.7	43.8
Apex Wash Seg 50	0.026	0.015	0.113	0.271	0.586	0	0	0	0	0
QC Arboretum Seg 47	0.047	0.004	0.844	3.391	9.787	0	0	0	0	0
Silver King Wash Seg 45	0.029	0.009	0.119	0.288	1.001	0	0	0	0	0
Happy Camp Canyon Seg 42	0.091	0.012	0.079	0.366	1.451	0	0	0	0	0
Arnet Creek Seg 46	0.023	0.010	0.253	1.143	3.532	2.2	0	0	0	0
Alamo Canyon Seg 49	0.025	0.004	0.032	0.136	0.555	0	0	0	0	0
Potts Canyon Seg 30	0.096	0.010	0.53	1.037	2.468	1.3	0	0	0	0
Reymert Wash Seg 28	0.044	0.009	0.052	0.224	0.91	0	0	0	0	0
QC Outlet Seg 25	0.068	0.005	0.284	1.173	5.409	33.1	22.3	20.3	21.6	22.3

The dissolved copper percent reductions presented in **Table 3-6** are developed using the estimated allowable dissolved copper load that complies with the most stringent criteria and the loads derived under the Existing Conditions Scenario. Therefore, these estimated reductions address dissolved copper loads from the mining operations, soil contamination in the Oak Flat subbasin due to historic smelter operations, and the copper loads from natural background in bedrock and soils. It is important to note that these allowable loads are extremely small under the less intense storms and consisting of a few grams of dissolved copper in 24-hours at most subbasin outlets.

The Existing Conditions Scenario modeling results also indicate that dissolved copper concentrations and loads are elevated at the outlet of the Oak Flat Basin contributing significant dissolved copper loads to Queen Creek. This is most probably due to past emissions from process operations, such as historic smelting operations that caused a copper contamination in the Oak Flat subbasin. Historic metal smelting in the Queen Creek watershed was without adequate air pollution controls and emitted from smoke stacks particulates high in metal contaminants that would then settle out of the air stream in the entire Queen Creek watershed but predominately in the Oak Flat basin because of the prevailing dominant winds. Metals deposition might have been at a relatively low concentration; however, the extended period of deposition over decades and the persistence of metals created soil contamination in the Oak Flat Subbasin and to a lesser degree over the entire Queen Creek watershed.

3.2.2 Dissolved Copper Mining-Background Scenario

In order to assess the contribution of the land-based mining loads, a second modeling scenario was implemented using the assumption that all the land-based mining-related copper loads are eliminated in the Queen Creek watershed. **Table 3-7** depicts the mining-areas identified by ADEQ and included in the Queen Creek HSPF model. A total of 772 acres, representing the footprint of abandoned, inactive, and semi-active mines, were included in the Queen Creek dissolved copper HSPF model.

This hypothetical scenario helps assess the impact of the copper mining loads on the instream water quality in Queen Creek. The PQUAL variables (POTFW, IOQC, and AOQC) used to estimate the mining-related non-point sources (land based) were set to zero in the calibrated hydrology dissolved copper input files used for of the five synthetic storms conditions. **Tables 3-8** and **3-9** summarize the results of the dissolved copper Mining-Background scenario along with the results of the Existing Conditions Scenario.

Table 3-7: Mining Areas in Queen Creek Watershed Model

Subbasin	Model Segment	Acres
Oak Flat	22	26
Queen Creek	94	32
	91	6
	38	8
	53	11
Apex Wash	88	39
	89	176
	50	29
Silver King Wash	11	1
	12	1
	14	8
RCC Superior Wash	90	163
	36	73
	92	77
Arnett Creek	63	1
Potts Canyon	9	1
	16	1
Reymert Wash	55	119
	Total Mining Acres	**772**
	Percent of Watershed Drainage Area	**1.3%**

Table 3-8: Existing Conditions and Mining-Background Scenarios - 24-Hour Average Dissolved Concentrations (µg/L)										
Subwatershed	Existing Conditions Scenario					Mining-Background Scenario Without Land-Based Mining Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	35.1	32.7	33.2	33.6	35.0	29.3	26.3	25.9	25.7	26.2
QC Hwy 60 Seg 17	20.6	18.6	18.8	18.8	19.2	19.6	17.8	18.0	18.0	18.4
QC Magma Avenue Seg 91	23.4	22.9	22.1	22.8	23.6	21.7	19.7	19.2	19.5	20.0
QC Mary Avenue Seg 38	22.3	13.5	16.9	17.3	18.6	20.3	11.6	14.6	15.0	15.9
QC below Mine Disch. Seg 92	12.5	0.8	12.3	14.1	15.4	11.0	0.7	10.6	12.2	13.2
Apex Wash Seg 50	13.1	3.9	11.4	13.0	14.5	1.8	0.5	1.7	2.0	2.2
QC Arboretum Seg 47	4.7	7.0	11.5	12.6	13.7	4.5	7.0	9.9	11.1	12.1
Silver King Wash Seg 45	14.3	9.1	10.1	10.3	10.5	13.6	8.7	9.5	9.6	9.8
Happy Camp Canyon Seg 42	10.2	10.6	13.0	14.5	15.3	10.2	10.6	13.0	14.5	15.3
Arnet Creek Seg 46	9.0	4.3	5.7	5.9	6.3	9.0	4.3	5.7	5.9	6.2
Alamo Canyon Seg 49	6.8	6.9	8.0	8.6	8.8	6.8	6.9	8.0	8.6	8.8
Potts Canyon Seg 30	10.6	6.0	7.3	7.3	7.4	10.6	6.0	7.2	7.3	7.4
Reymert Wash Seg 28	5.7	6.8	7.8	8.5	8.9	5.1	6.0	7.1	7.7	7.9
QC Outlet Seg 25	14.4	12.4	12.1	12.3	12.4	14.2	12.2	12.0	12.0	12.1
		Exceeds Chronic Criterion					Exceeds Acute Criteria			

Table 3-9: Existing Conditions and No-Mining Background Scenarios - 24-Hour Dissolved Copper Loads (kg)										
Subwatershed	Existing Conditions Scenario					Mining-Background Scenario Without Land-Based Mining Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	0.197	0.243	1.372	2.356	3.950	0.195	0.240	1.356	2.328	3.904
QC Hwy 60 Seg 17	0.040	0.080	0.704	1.318	2.306	0.038	0.076	0.676	1.265	2.213
QC Magma Avenue Seg 91	0.259	0.330	2.220	4.166	7.573	0.255	0.324	2.175	4.083	7.428
QC Mary Avenue Seg 38	0.255	0.300	2.151	4.070	7.472	0.251	0.295	2.107	3.990	7.329
QC below Mine Disch. Seg 92	0.079	0.003	1.118	2.906	6.230	0.077	0.003	1.096	2.843	6.080
Apex Wash Seg 50	0.023	0.004	0.086	0.236	0.569	0.004	0.001	0.013	0.037	0.091
QC Arboretum Seg 47	0.008	0.001	0.352	1.549	4.861	0.008	0.001	0.346	1.518	4.668
Silver King Wash Seg 45	0.021	0.004	0.060	0.148	0.524	0.020	0.004	0.055	0.137	0.484
Happy Camp Canyon Seg 42	0.028	0.004	0.031	0.161	0.673	0.028	0.004	0.031	0.161	0.673
Arnet Creek Seg 46	0.024	0.005	0.164	0.766	2.528	0.024	0.005	0.164	0.766	2.526
Alamo Canyon Seg 49	0.017	0.003	0.025	0.116	0.484	0.017	0.003	0.025	0.116	0.484
Potts Canyon Seg 30	0.097	0.006	0.370	0.723	1.745	0.097	0.006	0.370	0.723	1.743
Reymert Wash Seg 28	0.008	0.002	0.013	0.061	0.259	0.007	0.001	0.011	0.054	0.229
QC Outlet Seg 25	0.101	0.007	0.356	1.497	6.958	0.101	0.007	0.355	1.485	6.813

Table 3-8 indicates that both the existing-conditions and Mining-Background Scenarios have a similar impairment pattern mainly situated in the upper reaches of the watershed. This scenario indicates that the dissolved copper load contributions from the mining areas are not a major contributor and their complete removal will not impact the impairments predicted under the Existing Conditions Scenario. In other words, the simulated dissolved copper mining loads are relatively small when compared to the other contributions such as the copper in natural rock and soils and the historic smelter copper fallout in the Oak Flat subbasin and to some extent also the smelter copper fallout in the entire Queen Creek watershed.

Table 3-10 Subbasin Dissolved Load Percent Contribution from Mining Areas					
Subbasin	**2Y-1H**	**2Y-24H**	**10Y-24H**	**25Y-24H**	**100Y-24H**
Oak Flat Seg 22	1.3%	1.2%	1.2%	1.2%	1.2%
QC Hwy 60 Seg 17	3.9%	4.0%	4.0%	4.0%	4.0%
QC Magma Avenue Seg 91	1.6%	1.8%	2.0%	2.0%	1.9%
QC Mary Avenue Seg 38	1.6%	1.8%	2.0%	2.0%	1.9%
QC below Mine Disch. Seg 92	2.7%	9.6%	2.0%	2.2%	2.4%
Apex Wash Seg 50	83.7%	85.6%	84.5%	84.2%	84.0%
QC Arboretum Seg 47	1.6%	0.0%	1.7%	2.0%	4.0%
Silver King Wash Seg 45	7.1%	7.4%	8.0%	7.7%	7.7%
Happy Camp Canyon Seg 42	0.0%	0.0%	0.0%	0.0%	0.0%
Arnet Creek Seg 46	0.1%	0.2%	0.1%	0.1%	0.1%
Alamo Canyon Seg 49	0.0%	0.0%	0.0%	0.0%	0.0%
Potts Canyon Seg 30	0.1%	0.1%	0.0%	0.1%	0.1%
Reymert Wash Seg 28	8.4%	12.0%	10.4%	10.6%	11.3%
QC Outlet Seg 25	0.3%	1.3%	0.1%	0.8%	2.1%

Table 3-10 presents the load contribution (%) of dissolved copper from the mining areas at each subbasin outlet and at each model segment along the Queen Creek main stem. **Tables 3-9** and **3-10** indicate that the transported dissolved copper mining loads contributions at each subbasin outlet are extremely small at most subbasins in the Queen Creek watershed.

3.2.3 Oak Flat Dissolved Copper Scenario

An additional modeling scenario was implemented using the assumption that the dissolved copper loads from the Oak Flat subbasin are low enough that the resulting dissolved copper concentration at the Oak Flat subwatershed outlet (model-segment 22) meets the applicable standards. Such scenario will help evaluate the impact of the Oak Flat subbasin loads on the dissolved copper compliance at Magma Avenue (model-segment 91) and Mary Avenue (model-segment 38) and at downstream model segments located on the main stem of Queen Creek.

The PQUAL variables in the Oak Flat subwatershed were iteratively reduced until the resulting concentrations at the subbasin outlet (model-segment 22) comply with the applicable standards. **Table 3-11** depicts the resulting simulated dissolved copper concentrations and compliance analysis under the Oak Flat Scenario and the Existing Conditions Scenario. Reductions of the copper loads from smelter fall out will only impact segments located on the Queen Creek main stem downstream of the Oak Flat subbasin (highlighted in red in the subsequent tables). **Table 3-11** indicates that the reductions of copper smelter fallout loads in the Oak Flat subbasin will have a considerable impact on the downstream concentrations in segments located on the main stem of Queen Creek. However, these reductions in copper smelter fallout loads are not significant enough to be the sole cause of the impairment in the upper segments of the Queen Creek watershed. In fact and as shown in **Table 3-11**, significant decreases in the 24-hour average concentrations are predicted under the Oak flat scenario in the segment downstream of the Oak flat subbasin (model-segments 91, 38, and 92). However, the resulting concentrations in these segments are not in compliance with the acute and/or chronic criteria. This is also due to extremely low hardness of the water observed at these segments resulting in very stringent copper criteria.

Table 3-11: Existing Conditions and Oak Flat Scenarios - 24-Hour Average Dissolved Concentrations (µg/L)										
Subwatershed	Existing Conditions Scenario					Oak Flat Scenario - Without Copper Smelter Fallout Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	35.1	32.7	33.2	33.6	35.0	2.72	2.71	2.76	2.78	2.90
QC Hwy 60 Seg 17	20.6	18.6	18.8	18.8	19.2	20.6	18.6	18.8	18.8	19.2
QC Magma Avenue Seg 91	23.4	22.9	22.1	22.8	23.6	15.7	9.7	11.5	11.7	11.9
QC Mary Avenue Seg 38	22.3	13.5	16.9	17.3	18.6	14.3	5.8	8.9	9.4	10.0
QC below Mine Disch. Seg 92	12.5	0.8	12.3	14.1	15.4	11.0	0.8	6.6	8.0	8.9
Apex Wash Seg 50	13.1	3.9	11.4	13.0	14.5	13.1	3.9	11.4	13.0	14.5
QC Arboretum Seg 47	4.7	7.0	11.5	12.6	13.7	4.3	7.0	6.5	8.0	9.2
Silver King Wash Seg 45	14.3	9.1	10.1	10.3	10.5	14.3	9.1	10.1	10.3	10.5
Happy Camp Canyon Seg 42	10.2	10.6	13.0	14.5	15.3	10.2	10.6	13.0	14.5	15.3
Arnet Creek Seg 46	9.0	4.3	5.7	5.9	6.3	9.0	4.3	5.7	5.9	6.3
Alamo Canyon Seg 49	6.8	6.9	8.0	8.6	8.8	6.8	6.9	8.0	8.6	8.8
Potts Canyon Seg 30	10.6	6.0	7.3	7.3	7.4	10.6	6.0	7.3	7.3	7.4
Reymert Wash Seg 28	5.7	6.8	7.8	8.5	8.9	5.7	6.8	7.8	8.5	8.9
QC Outlet Seg 25	14.4	12.4	12.1	12.3	12.4	14.4	12.4	12.1	11.7	11.7
		Exceeds Chronic Criterion					**Exceeds Acute Criteria**			

Table 3-12: Existing Conditions and Oak Flat Scenarios 24-Hour Dissolved Copper Loads (kg)										
Subwatershed	Existing Conditions Scenario					Oak Flat Scenario				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	0.197	0.243	1.372	2.356	3.950	0.016	0.020	0.113	0.194	0.325
QC Hwy 60 Seg 17	0.040	0.080	0.704	1.318	2.306	0.040	0.080	0.704	1.318	2.306
QC Magma Avenue Seg 91	**0.259**	**0.330**	**2.220**	**4.166**	**7.573**	**0.078**	**0.115**	**0.975**	**2.021**	**3.976**
QC Mary Avenue Seg 38	**0.255**	**0.300**	**2.151**	**4.070**	**7.472**	**0.077**	**0.102**	**0.936**	**1.966**	**3.922**
QC below Mine Disch. Seg 92	**0.079**	**0.003**	**1.118**	**2.906**	**6.230**	**0.031**	**0.003**	**0.477**	**1.460**	**3.489**
Apex Wash Seg 50	0.023	0.004	0.086	0.236	0.569	0.023	0.004	0.086	0.236	0.569
QC Arboretum Seg 47	**0.008**	**0.001**	**0.352**	**1.549**	**4.861**	**0.007**	**0.001**	**0.126**	**0.763**	**2.967**
Silver King Wash Seg 45	0.021	0.004	0.060	0.148	0.524	0.021	0.004	0.060	0.148	0.524
Happy Camp Canyon Seg 42	0.028	0.004	0.031	0.161	0.673	0.028	0.004	0.031	0.161	0.673
Arnet Creek Seg 46	0.024	0.005	0.164	0.766	2.528	0.024	0.005	0.164	0.766	2.528
Alamo Canyon Seg 49	0.017	0.003	0.025	0.116	0.484	0.017	0.003	0.025	0.116	0.484
Potts Canyon Seg 30	0.097	0.006	0.370	0.723	1.745	0.097	0.006	0.370	0.723	1.745
Reymert Wash Seg 28	0.008	0.002	0.013	0.061	0.259	0.008	0.002	0.013	0.061	0.259
QC Outlet Seg 25	**0.101**	**0.007**	**0.356**	**1.497**	**6.958**	**0.101**	**0.007**	**0.356**	**1.218**	**5.867**

Table 3-12 presents the resulting 24-hour dissolved copper loads under the Existing Conditions and the Oak Flat scenarios. **Table 3-13** uses the results presented in **Table 3-13** and summarizes the percent contribution of dissolved copper smelter fallout loads in the model-segments downstream of the Oak Flat subbasin.

Table 3-13: Oak Flat Scenario – Smelter Fallout Dissolved Copper Load Contribution					
	2Y-1H	**2Y-24H**	**10Y-24H**	**25Y-24H**	**100Y-24H**
Oak Flat Seg 22	91.7%	91.7%	91.3%	91.3%	91.8%
QC Hwy 60 Seg 17	0.0%	0.0%	0.0%	0.0%	0.0%
QC Magma Avenue Seg 91	69.7%	65.2%	55.8%	51.2%	47.5%
QC Mary Avenue Seg 38	70.0%	66.0%	56.2%	51.5%	47.5%
QC below Mine Disch. Seg 92	60.6%	0.0%	57.1%	49.5%	44.0%
Apex Wash Seg 50	0.0%	0.0%	0.0%	0.0%	0.0%
QC Arboretum Seg 47	10.6%	0.0%	63.9%	50.5%	39.0%
Silver King Wash Seg 45	0.0%	0.0%	0.0%	0.0%	0.0%
Happy Camp Canyon Seg 42	0.0%	0.0%	0.0%	0.0%	0.0%
Arnet Creek Seg 46	0.0%	0.0%	0.0%	0.0%	0.0%
Alamo Canyon Seg 49	0.0%	0.0%	0.0%	0.0%	0.0%
Potts Canyon Seg 30	0.0%	0.0%	0.0%	0.0%	0.0%
Reymert Wash Seg 28	0.0%	0.0%	0.0%	0.0%	0.0%
QC Outlet Seg 25	0.00%	0.00%	0.01%	18.6%	15.7%
Total All Segments	**50.9%**	**64.2%**	**50.6%**	**44.2%**	**35.8%**

Table 3-13 indicates that the Oak Flat transported dissolved copper smelter fallout loads constitute a significant proportion of the copper loads at the segments located downstream on the main stem of Queen Creek (model-segments 91, 38, 92, and 47). For the segments immediately downstream of the Oak Flat subbasin (model-segments 91, 38, and 92), under the various synthetic storms the copper smelter fallout loads constitute between 44 and 70 percent of the Existing Conditions copper load at these segments.

Under the low-frequency storms (2 year-1-hour and 2 year-24-hour) the copper loads from the Oak Flat subbasin do not impact the outlet of the watershed; i.e., are not transported all the way down to the outlet of the watershed (model-segment 25). Under the 10-year 24-hour storm the copper smelter load in Oak Flat subbasin has an insignificant impact on the load in the outlet of the watershed. However, under the higher frequency storms (25-year 24-hour and 100-year 24-hour) the contribution of the copper smelter fallout load in the Oak Flat subbasin constitute 16 to 19 percent of the Existing Conditions scenario dissolved copper load at the outlet of the Queen Creek watershed.

The Oak Flat scenario addressed the contribution of the anthropogenic contamination of the soils in the Oak Subbasin and highlighted the magnitude of these loads and their impact on the downstream segments in the Queen Creek watershed. The key conclusion that can be drawn from the Oak Flat scenario is that the copper contents in soil and rocks, in other locations than the Oak Flat subbasin, are still significant enough to cause exceedances of the dissolved copper criteria. The Mining-Background scenario indicated that the dissolved copper mining loads transported at the outlet of the subbasins and in the main stem of Queen Creek are not a significant source of copper in the watershed.

In summary and based on the implementation of the various dissolved copper scenarios, it is apparent that the copper content in soils and rocks is the dominant factor causing the exceedances of the dissolved copper criteria in the various segments of the Queen Creek watershed. This copper content in soils and rocks is a combination of the natural copper content in soils and the historic copper smelter fallout in the entire Queen Creek watershed.

3.3 Total Lead Model Implementation

The Queen Creek HSPF total lead calibration follows the same strategy as the one for dissolved copper. The QALSD option of the PQAL routine was also used to simulate the land-based washoff of total lead. Using the observed total lead instream observations as a guide (**Table 2-3),** the PQUAL parameters were estimated iteratively until an acceptable fit is reached between observed and simulated total lead concentrations. Using the hard rock lead data as a guide, the parameters were further refined to achieve comparable observed and simulated average dissolved concentrations. **Table 3-14** depicts the final PQUAL value for each soil landuse type within each of the sub-basins in the Queen Creek watershed. The key observation is that the input concentrations of total lead in the interflow and base flow are much lower than the ones for dissolved copper. These concentrations were lowered to mimic the low observed base flow lead concentrations.

The detached sediment POTFW values were also adjusted to match the peak total lead values observed during storm events. This is consistent with the observed data indicating that total lead is highly correlated with precipitation events where most of the load is associated with sediments. **Figures 3-5** and **3-6** depict the dissolved copper calibration at Oak Flat (model-segment 22) and at Silver King Wash (model-segment 45), respectively. The complete total lead calibration results presented in **Appendix C** indicate a robust agreement between observed and simulated total lead concentrations.

Table 3-14: Total Lead HSPF PQUAL Parameters Summary by Sub-Basin and Soil-Landuse Type

Geology Landuse	Parameter	Potts Canyon	Happy Camp Canyon	Silver King Wash	Apex Wash	RCC Superior Wash	Queen Creek	Oak Flat	Arnett Creek	Alamo Canyon	Reymert Wash
Pinal Schist	Pb Conc. (ug/L)	2.8	5.0	6.2					2.2	1.0	2.1
	POTFW	2,884	5,150	6,386	-	-	-	-	2,266	1,030	2,163
	IOQC	0.079	0.142	0.175					0.062	0.028	0.059
	AOQC	0.079	0.142	0.175					0.062	0.028	0.059
Apache Group	Pb Conc. (ug/L)	4.0	1.0	2.5	1.0	2.0	2.0		2.4		
	POTFW	4,120	1,030	2,575	1,030	2,060	2,060		2,472	-	-
	IOQC	0.113	0.028	0.071	0.028	0.057	0.057		0.068	-	-
	AOQC	0.113	0.028	0.071	0.028	0.057	0.057		0.068	-	-
Granite Crystalline	Pb Conc. (ug/L)	1.0		1.5			2.3		2.2	1.4	2.5
	POTFW	1,030	-	1,545	-	-	2,369	-	2,266	1,442	2,575
	IOQC	0.028	-	0.042	-	-	0.065	-	0.062	0.040	0.071
	AOQC	0.028	-	0.042	-	-	0.065	-	0.062	0.040	0.071
Volcanic	Pb Conc. (ug/L)	7.0	1.5	1.0	3.0		7.0		3.6	0.9	
	POTFW	7,210	1,545	1,030	3,090		7,210		3,708	927	-
	IOQC	0.198	0.042	0.028	0.085		0.198		0.102	0.025	-
	AOQC	0.198	0.042	0.028	0.085	-	0.198		0.102	0.025	-
Alluvium	Pb Conc. (ug/L)	2.0	5.0	3.0	4.9	4.7	4.7		2.0	1.0	1.0
	POTFW	2,060	5,150	3,090	5,047	4,841	4,841	-	2,060	1,030	1,030
	IOQC	0.057	0.142	0.085	0.139	0.133	0.133	-	0.057	0.028	0.028
	AOQC	0.057	0.142	0.085	0.139	0.133	0.133	-	0.057	0.028	0.028
Mining Milling Metal	Pb Conc. (ug/L)	32		290	52.0	50	50	30	14		300
	POTFW	32,960	-	2.99E+05	53,560	51500	51500	30900	13905	-	309000
	IOQC	0.906	-	8.207	1.472	0.415	1.415	0.849	0.382	-	8.490

Table 3-14: Total Lead HSPF PQUAL Parameters Summary by Sub-Basin and Soil-Landuse Type											
Geology Landuse	**Parameter**	**Potts Canyon**	**Happy Camp Canyon**	**Silver King Wash**	**Apex Wash**	**RCC Superior Wash**	**Queen Creek**	**Oak Flat**	**Arnett Creek**	**Alamo Canyon**	**Reymert Wash**
	AOQC	0.906	-	8.207	1.472	1.415	1.415	0.849	0.382	-	8.490
Sedimentary	**Pb Conc. (ug/L)**	5		4	5	2	2		2	2	
	POTFW	5,150	2,060	4,120	5047	2,060	2,060	-	2,060	2,060	-
	IOQC	0.142	0.057	0.113	0.138	0.057	0.057	-	0.057	0.057	-
	AOQC	0.142	0.057	0.113	0.138	0.057	0.057	-	0.057	0.057	-
Tuff	**Pb Conc. (ug/L)**		2.0	3.0	1.9	2.0	2.0	1.6	1.2	2.0	
	POTFW	-	2,060	3,090	1,957	2,060	2,060	1,648	1,236	2,060	-
	IOQC	-	0.057	0.085	0.054	0.057	0.057	0.045	0.034	0.057	-
	AOQC	-	0.057	0.085	0.054	0.057	0.057	0.045	0.034	0.057	-
Urban Industrial	**Pb Conc. (ug/L)**				7	7	7				
	POTFW	-	-	-	7,210	7,210	7,210	-	-	-	-
	IOQC	-	-	-	0.198	0.198	0.198	-	-	-	-
	AOQC	-	-	-	0.198	0.198	0.198	-	-	-	-

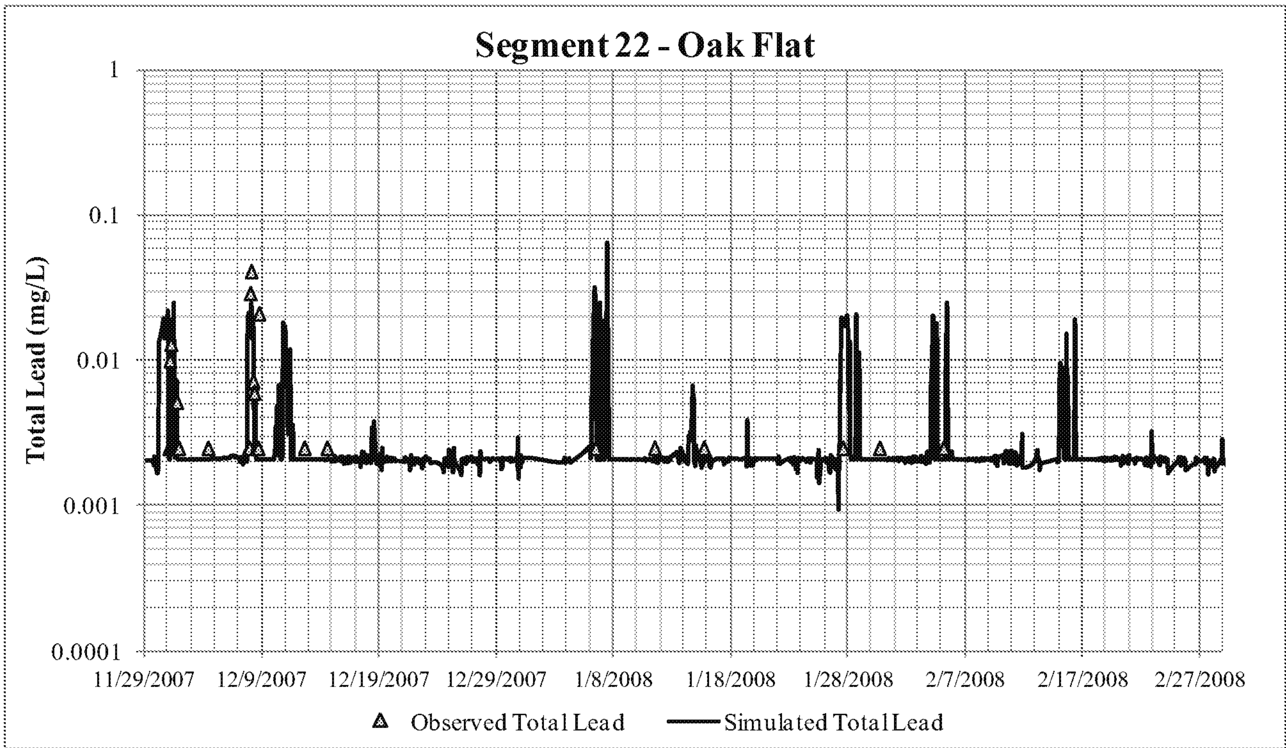

Figure 3-5: Observed and Simulated Total Lead at Model-Segment 22 – Oak Flat

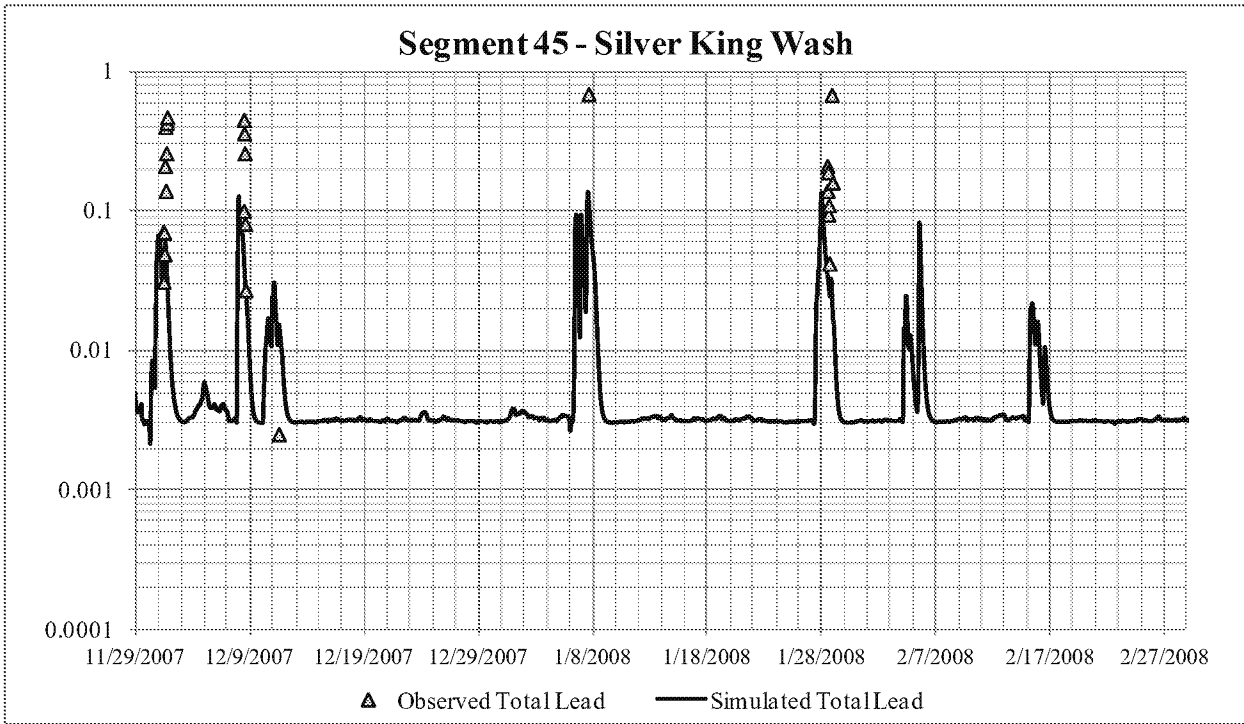

Figure 3-6: Observed and Simulated Total Lead at Model-Segment 45 – Silver King Wash

3.3.1 Total Lead Existing Conditions and Mining-Background Scenarios

Similar to the dissolved copper simulations, the Existing Conditions and the Mining-Background scenarios, described in sections 3.3.1 and 3.3.2, were also implemented for total lead to derive the concentrations and loads under the various synthetic storm conditions. The resulting 24-hour average total lead concentrations and the 24-hour loads are depicted for each subbasin and synthetic storm in **Tables 3-15** and **3-16,** respectively. Under each scenario and synthetic storm condition, the compliance with the FBC criteria was assessed at each segment using the 24-hour average predicted total lead concentration.

Table 3-15: Simulated 24-Hour Average Total Lead Concentrations by Scenario and Storm Event (µg/L)											
Subwatershed	FBC Criterion (ug/L)	Existing Conditions Scenario					Mining-Background Scenario Without Land-Based Mining Loads				
		2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	15	5.1	8.5	11.3	13.2	15.5	4.6	6.1	8.3	9.7	11.4
QC Hwy 60 Seg 17	15	13.5	10.1	13.5	15.7	19.1	10.3	7.9	10.6	12.3	14.9
QC Magma Avenue Seg 91	15	8.7	7.9	10.5	12.4	14.6	6.9	6.1	8.1	9.6	11.4
QC Mary Avenue Seg 38	15	9.1	4.7	8.4	9.8	11.9	7.2	3.6	6.6	7.7	9.4
QC below Mine Disch. Seg 92	15	3.3	0.6	7.1	9.1	11.2	2.7	0.3	5.6	7.1	8.7
Apex Wash Seg 50	15	13.4	4.0	15.5	18.4	21.5	8.4	2.5	9.7	11.5	13.5
QC Arboretum Seg 47	15	6.0	9.7	10.0	11.2	13.0	5.5	9.7	8.5	9.5	11.0
Silver King Wash Seg 45	15	42.5	34.7	34.6	48.9	76.9	12.8	9.6	10.7	13.2	19.4
Happy Camp Canyon Seg 42	15	7.2	8.1	7.5	9.5	10.1	7.2	8.1	7.5	9.5	10.1
Arnet Creek Seg 46	15	9.7	5.0	8.4	8.7	9.5	9.7	5.0	8.4	8.7	9.5
Alamo Canyon Seg 49	15	1.8	4.5	3.3	4.2	4.6	1.8	4.5	3.3	4.2	4.6
Potts Canyon Seg 30	15	9.3	5.2	7.9	8.1	9.2	9.3	5.2	7.9	8.1	9.2
Reymert Wash Seg 28	15	178.5	600.3	248.0	384.6	481.0	3.8	8.1	5.7	7.6	8.3
QC Outlet Seg 25	15	34.0	45.4	21.9	22.8	29.9	14.2	8.4	10.1	10.9	12.0

Average Concentration Exceeds FBC Criterion

Table 3-16: Simulated 24-Hour Total Lead Loads by Scenario and Storm Event (kg)										
Subwatershed	Existing Conditions					Background Scenario - Without Land-Based Mining Loads				
	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H	2Yr 1H	2Yr 24H	10Yr 24H	25Yr 24H	100Yr 24H
Oak Flat Seg 22	0.108	0.072	0.610	1.124	1.986	0.079	0.052	0.454	0.841	1.490
QC Hwy 60 Seg 17	0.063	0.043	0.723	1.588	3.101	0.049	0.033	0.563	1.237	2.415
QC Magma Avenue Seg 91	0.191	0.127	1.412	3.059	6.209	0.147	0.097	1.094	2.410	4.980
QC Mary Avenue Seg 38	0.190	0.120	1.399	3.031	6.186	0.146	0.092	1.083	2.388	4.960
QC below Mine Disch. Seg 92	0.079	0.003	0.842	2.416	5.734	0.060	0.001	0.661	1.913	4.512
Apex Wash Seg 50	0.039	0.004	0.128	0.373	0.936	0.025	0.003	0.080	0.234	0.587
QC Arboretum Seg 47	0.014	0.001	0.301	1.507	5.245	0.013	0.001	0.238	1.219	4.258
Silver King Wash Seg 45	0.161	0.023	0.219	0.971	4.866	0.044	0.006	0.066	0.247	1.177
Happy Camp Canyon Seg 42	0.024	0.003	0.015	0.100	0.478	0.024	0.003	0.015	0.100	0.478
Arnet Creek Seg 46	0.047	0.005	0.246	1.309	4.573	0.047	0.005	0.246	1.309	4.573
Alamo Canyon Seg 49	0.011	0.002	0.008	0.053	0.286	0.011	0.002	0.008	0.053	0.286
Potts Canyon Seg 30	0.202	0.004	0.408	0.942	2.934	0.202	0.004	0.408	0.942	2.934
Reymert Wash Seg 28	0.391	0.156	0.293	2.439	17.448	0.009	0.002	0.007	0.047	0.267
QC Outlet Seg 25	0.323	0.040	0.489	2.460	21.598	0.206	0.006	0.403	1.890	9.675

Under the Existing Conditions Scenario (**Table 3-15**) the compliance with the FBC total lead criteria indicates that Silver King Wash (model-segment 45) Reymert Wash (model-segment 28) and the Queen Creek watershed outlet (model-segment 25) are the only three segments not in compliance under all five synthetic storm conditions. These 3 segments are not listed as impaired for total lead under the current 303(d) list. The Existing Conditions Scenario indicates that the simulated average total lead concentrations at the Apex Wash subbasin (model-segment 50) exceed the FBC criteria under the 10-year 24-hour, the 25-year 24-hour, and the 100-year 24-hour storm conditions. This segment is also not listed under the current 303(d) list and most of the observed total lead data collected recently in 2009 and 2010 shows elevated total lead concentrations (**Table 2-3**). Under the Existing Conditions Scenario the 100-year 24-hour storm event triggers a minor impairment at the Oak Flat subbasin (model-segment 22). The 25-year 24-hour and the 100-year 24-hour storm events also result in total lead exceedances of the FBC criteria at Queen Creek model-segment 17.

The results of the Mining-Background scenario shown in **Table 3-15**, indicate that all model-segments are in compliance with the total lead criteria expect the Silver King Wash (model-segment 45) which shows an exceedance of the FBC criteria under the 100-year 24-hour storm. **Table 3-15** suggests that the land-based mining loads are the main cause of the total lead impairment in Queen Creek.

Table 3-16 depicts the estimated 24-hour average total lead loads under the Existing Conditions and the Mining-Background scenarios. The information presented in **Table 3-17** can be used as a starting point for the development and implementation of allocations modeling-scenarios to derive the required percent reductions from the mining sources in the impaired subbasins in the Queen Creek watershed.

4.0 References

Arizona Department of Environmental Quality, Surface Water Section. 2006. Pinto Creek Phase II TMDL Modeling Report

Arizona Department of Environmental Quality, Surface Water Section. 2010. Interim Queen Creek TMDL Modeling Report.

U.S. Environmental Protection Agency (EPA). 2000. Estimating Hydrology and Hydraulic Parameters for HSPF. EPA-823-R00-012

U.S. Environmental Protection Agency (EPA). 2001. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), Version 3 Washington, DC.

U.S. Environmental Protection Agency (EPA). November 2008. The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. EPA/600/R-08/134 ARS/233046

Table of Contents

[TOC \o "1-3" \h \z \u]

List of Figures

List of Tables